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UNITED STATES AIR FORCE RESEARCH LABORATORY

DEVELOPMENT OF A DISTRIBUTED TRAINING AND RESEARCH NETWORK

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14. ABSTRACT
This paper describes the creation of the Distributed Mission Training Research Network (DMT-RNet), the rationale behind its creation, and its capabilities. Information is provided about the various simulation platforms included in the network and how they have become integrated to enable a common battlespace, including platforms developed specifically for use in the DMT-RNet and platforms that were developed independently. The latest interoperability tests and linkages created are described. Fidelity issues, agent technology, and training implications are discussed.

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Development of a Distributed Training and Research Network

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INTRODUCTION

Extensive and high-quality training is central to the maintenance of United States military dominance. The training, realistic and extensive, includes many sessions of highly monitored, live-fire exercises necessary to refine combat experience and skill. In the Air Force, these live-fire exercises include highly renowned mission rehearsal training such as Red Flag and Close Air Support Exercises.

However, live-fire sessions also have inherent disadvantages. These include significant limitations with regard to risk, complexity, and uncertainty in mission scenarios. Limitations are primarily driven by safety issues, for training participants and

inhabitants in and around training exercise areas. Environmental issues (e.g., pollution from emissions, noise, hazardous materials) also restrict the use of live-fire exercises. Finally, high cost is also a significant limiting factor.

There are approximately 400,000 US Air Force military personnel. Most personnel go through a month or more of training per year, every year of their 30-year careers. One should also consider nearly the same numbers of personnel from the Navy, Army, and the Marines who also require training. If one also includes all the government civilians who are equally required to go through training, the costs are staggering.

Today's international climate of dispersed operations in a multitude of differing battlefield situations has brought distributed training to the forefront of making training better suited to warrior needs. Each battlefield situation is distinct and the technology, sociology, and psychology of war rapidly changes. What is the most efficient, effective, and least costly way to train our warriors?

Training as a continuous cycle is quite costly. Warriors are dispersed globally and cannot simply leave in the middle of operations to go to the United States for schoolhouse (i.e., residing at a specific location) training. In addition, the mass of travel associated with bringing personnel stateside for training would result in exorbitant cost. We must be able to train personnel from the operational field and at the same time train stateside personnel who have yet to go into peacekeeping or battlefield operations.

Reserves and National Guard personnel are unable to train in an active duty schoolhouse for a prolonged amount of time because they are not normally on fulltime active duty status, yet they are required to be as fully capable as their active duty counterparts. Lately, reservist and guard personnel are being deployed into battlefield operations in ever increasing numbers. According to Newsmax.com (2002), "About 50,000 U.S. military personnel are in the region fighting in Operation Enduring Freedom, the Pentagon said. There are three aircraft carriers and numerous smaller ships in the waters south of Afghanistan. More than 40,000 reservists have been activated, most for homeland defense duties, but some for combat inside Afghanistan's borders."

It would cost approximately $83.4 million in per diem costs to ship 50,000 personnel stateside for two weeks of training assuming they travel to multiple training

bases across the country for specialty training. This does not include the costs of multiple aircraft transports, fuel, maintenance, and scheduled crew downtime.

Personnel assigned in the United States normally travel from their base to their training site by commercial aircraft. The approximate cost of $83.4 million in per diem costs for 50,000 personnel stays the same but now the costs of airfare are added. If a typical round-trip flight costs approximately $400, multiplied by 50,000 personnel, the airfare costs equate to $20 million. Now, add the per diem costs to the airfare costs and you get $103.4 million for 50,000 personnel for two weeks of training.

For several years now, the Air Force has focused many resources into the development of Distributed Mission Training (DMT) to overcome these limitations. The purpose of DMT is to allow people who are geographically dispersed to still train together using networks of highly realistic equipment-based simulators. These simulators enable complex and challenging battlespace scenarios that are not restricted to particular geographic areas, tactics, maneuvers, or limitations in assets/manpower. Highly experienced tacticians deployed worldwide can brief, mission rehearse, and debrief with novice trainees located at various sites. Advantages range far beyond cost savings.

The cost savings associated with DMT are indeed significant. A person in San Antonio can train one day with someone who is in Arizona, and the next day with someone in Florida. The benefits of training in teams are retained, while eliminating much of the traveling that is necessary to do so. These savings become obvious when considering the travel costs of flying people around the country

For examples of DMT technologies that have been well developed and are currently paying back their invested money in the form of these savings, see Crane and Guckenberger (2000); Crane, Schiflett, and Oser (2000); Crane (1999); and Crane and Kang (1999).

DMT-RNet: THE NEXT STEP

So far, DMT technologies have focused on high-technology simulations networked for geographically dispersed personnel for the purpose of mission rehearsal. This technology continues to be developed as its role in training becomes more central.

Air Force technology, originally aimed at reductions of physiological limitations such as g-tolerance, is now focused on enhancement of cognitive functions such as situation awareness, problem solving, and decision making. The development and increased use of uninhabited reconnaissance and intelligence gathering aircraft underlines the growing and central role of the human as leader and decision maker as opposed to emphasis on physiological and psychomotor skills associated with piloting in air-to-air combat missions.

However, while the use and importance of DMT-based training increases, we must admit to significant limitations in our understanding of skill acquisition and training effectiveness in large-scale, multi-team training scenarios. DMT is a new approach in training and thus many questions arise: How many live trainees should the training target in a session? How can training requirements be generated and met for multiple positions within a single session? How do we ensure the necessary levels of control? What is the best ratio of live trainees, live confederates, and agent-based constructive forces? How can one train and assess adaptive problem solving in controlled circumstances? How shall performance be assessed and displayed? What are the optimal timing, format, and distribution of performance feedback?

At Brooks City Base in San Antonio, the Information Systems Training Branch of the Warfighter Training Research Division is taking the next leap forward in developing the Distributed Mission Training Research Network (Barnes, Elliott, Tessier, & Petrov, 2002). While other DMT technologies have focused on classified training infrastructures, DMT-RNet focuses on training optimization using available unclassified infrastructures allowing controlled and multidiscipline university-based investigations of multi-team training systems. DMT-RNet establishes the first unclassified military network of computer-based synthetic task research platforms used by a consortium of government, universities, and small businesses. Each platform is an analogue of the cognitive demands of a military operational performance domain, such that naïve trainees can be quickly trained in the overall responsibilities and decision making of a particular operational role, e.g., a command and control (C2) weapons controller, or an Uninhabited Aerial Vehicle (UAV) operator. These platforms were developed based on cognitive task analyses of selected Air Force operations. In addition, they were engineered to enable

fine-tuned manipulations of display features, information flow, and scenario events. Performance data are collected and displayed online and in extensive data output files. As these data are analyzed, research findings will be applied to the advancement of DMT technology.

FIDELITY ISSUES

DMT enables highly realistic mission rehearsal based on networks of high-fidelity simulations that immerse personnel in virtual battlespace scenarios. These simulators are highly realistic, in terms of equipment characteristics and procedures used in an operational setting. They look and function just like the "real thing." In fact, some of these systems are fully functional as operating USAF systems—the main difference being the added capacity to connect and operate within a simulation network. Because these simulations strive for maximum realism, they must run in classified mode within its own dedicated network, thus restricting data analysis and publication. Further, systems such as these are extremely expensive, difficult to deploy and utilize in field settings, and less available for use, relative to PC-based systems.

Van den Bosch and Riemersma (2003, in this volume), elaborate further on the problems of high physical fidelity systems. The goal of operational missions is to minimize failure, while the goal of training is to learn and improve knowledge and skills. These goals are often incongruent. Operational environments are typically complex, dynamic, and unpredictable, which, conflicts with the fundamental requirement of training and measurement of having control over task content, so that it is known which events will occur at a specified point in the scenario (Fowlkes, Dwyer, Oser & Salas, 1998). Thus, the "train as you fight" philosophy is in conflict with the didactic principle of control. Control is necessary to make sure that the content and complexity of scenarios is in accordance with the phase of training.

Fowlkes et al. (1998) argue that the factors that make wargames exciting (complex, dynamic, and unpredictable) are the very factors that make them troublesome from a training standpoint. Control of task content is a fundamental requirement of training in order for it to be known what is being measured. This requirement is clearly at odds with

the intentionally dynamic nature of war fighting that is simulated in war games (van den Bosch & Riemersma, 2003).

In contrast to many high physical fidelity systems, DMT-RNet systems enable systematic investigations in unclassified mode and establish the infrastructure to conduct multi-level investigations of operational performance using less costly PC-based systems. The DMT-RNet collaborative research program leverages emerging Internet-2 (I-2) capabilities to connect distributed PC-based simulation systems and create complex environments for multi-operator training and performance research. These systems can be readily deployed to operational field settings and enable cost-effective distributed training wherever Internet access is available.

DMT-RNet systems will not be total replications of operational systems (Barnes, Elliott, & Entin, 2001). Instead, these synthetic team task systems will capture the cognitive and task demands of most interest to trainers and researchers (Elliott, Dalrymple, Regian, & Schiflett, 2001). For example, a PC-based system may simplify the "button pressing" procedures required in an actual operational system and instead focus on display characteristics, decision making processes, tactics, strategies, and/or teamwork functions. Convincing arguments have been made for the relevance of systems that are based on psychological fidelity and the absolute need for internal validity for the advancement of scientific knowledge (Berkowitz & Donnerstein, 1982; Cook & Campbell, 1979; Mook, 1983; Kozlowski & DeShon, this volume). The research platforms used in the initial phases of the DMT-RNet program were developed to represent the underlying cognitive and decision making task demands of Airborne Warning and Control System (AWACS) Weapons Director (WD) teams, based on multiple investigations of cognitive and functional aspects of this performance domain (Coovert, et al., 1999).

Another benefit of a synthetic task environment is the variety of subjects that can participate in the research. High-fidelity simulators are so close to reality that they necessitate expert operators as subjects. There is a shortage of personnel in the Air Force in general, and particularly for high-expertise tactical operators. The operational Air Force simply can't spare these people for all of its research issues, regardless of potential payoff from these investigations. Systems such as the Distributed Dynamic Decision-

making Network (DDD-Net) and the Agent-Enabled Decision Guide Environment (AEDGE) (discussed in this chapter) can use naive subjects and train them quickly to use the system, thus allowing skill acquisition to focus on underlying tactics, strategies, teamwork, or other training/research objectives while limiting the commitment of operational personnel and funds for the Air Force. They also allow researchers to study knowledge-based skill acquisition processes and interventions (e.g., training content and delivery, distribution and display of information, and coaching and decision support capabilities).

The issue of knowledge acquisition is important when working with training objectives that are remotely administered and scored, for example, Advanced Distributed Learning (ADL). To achieve optimal content and delivery, we must use cognitive principles to identify specific knowledge structures required to coordinate, interpret, and predict the activities of others. This is fundamental to measure and enhance individual and team situational awareness. We must measure, from a functional and cognitive perspective, how often people should update their knowledge, by what method, and how it should be shared in a team.

DMT-RNet Platforms: DDD-Net

Barnes, et al. (2001) discuss the initial phase of the DMT-RNet project that utilized the (DDD) team-in-the-loop simulation environment (Hess, MacMillan, Elliott, & Schiflett, 1999; Kleinman & Serfaty, 1989). The DMT-RNet program developed an internet-based version of the DDD, the DDD-Net, which allows players in distributed locations to connect and perform a distributed mission in real time. The DDD-Net is an internet-ready version of a Linux-based collaborative gaming space that connects players to each other and to others, such as observers, confederates, trainers, or researchers (see MacMillan, et al., (1998).

In the DDD-Net, observers at any location in the network are able to observe the scenario play in real time. They can view the screen display and electronic communications of any player and communicate to one another via email or voice. In

addition, the DDD-Net can connect players to one another for interactive mission planning, debriefings, and after-action reviews.

DDD simulations in general are based on broad C2 functions and have been demonstrated to elicit important team-oriented cognitive processes such as communication and coordination, resource allocation and sharing, and decision making. For this initial effort, the DDD software and scenarios were developed as analogues to USAF operational performance domains.

Specifically, this version of the DDD-Net was developed to represent the underlying cognitive and decision-making task demands of AWACS WD teams, based on multiple investigations of cognitive and functional aspects of this performance domain (Coovert, et al., 2001). Further development resulted in a scenario that emulates three military C2 teams: the USAF AWACS team, another USAF ground-based C2 team, and a third Navy airborne C2 team.

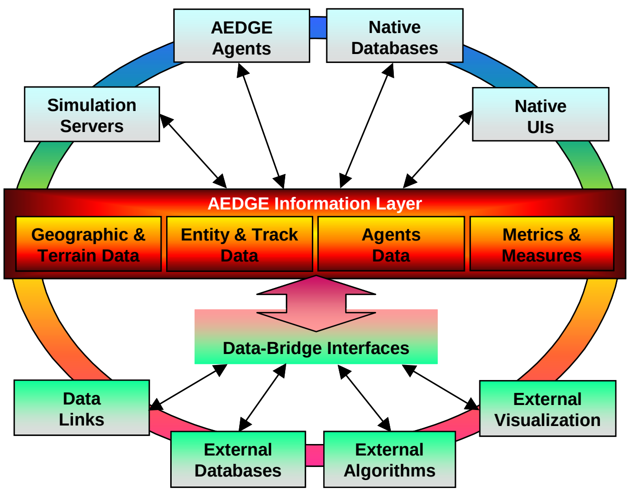
Other platforms, also based on USAF operations, will be utilized and networked into DMT-RNet in future efforts. These additional systems have also been developed within this program, and each provides an integrated, internet-enabled, collaborative training space that supports three integrated capabilities: distributed team performance, distributed assessment and distributed training (Elliott, Chaiken, Stoyen, Petrov, & Riddle, 2000).

DMT-RNet Platforms: AEDGE™ [1]

For example, the AWACS-AEDGE™ is another internet-ready platform that emulates AWACS WD functions, but uses a java-based architecture composed of a unique federation of intelligent agents. These agents generate and execute scenario function, data collection, decision support, and emulate WD roles within the scenario. This platform allows participants to play with or against agent-based, simulated friendly and/or enemy forces. It can also execute scenarios in all-agent mode, providing what-if analyses of different scenario characteristics (e.g., number and location of assets and targets). These advanced agent-based capabilities will provide further improvements to internet-based training and research. It was developed specifically for the DMT-RNet

[1] AEDGE, AWACS-AEDGE, and 21CSI are registered trademarks of 21st Century Systems Inc.

(Barnes, Elliott, et al., 2002). The AWACS-AEDGE, built using 21st Century Systems Inc.'s AEDGE™ infrastructure, is a distributed, real-time team decision support environment comprised of simulators, entity framework, intelligent agents, and user interfaces. The environment supports a wide variety of air, sea (surface and sub-surface), and ground assets in a combat environment (Chiara & Stoyen, 1997), primarily based on the roles and responsibilities of AWACS WD team members. The environment has been tested with an excess of 200 physical entities (planes, ships, surface-to-air (SAM) sites, etc.) operating with realistic yet non-classified performance characteristics in an interactive environment in which real-time decision support is available to each WD.



21CSI's AEDGE™ Product

The behavior and decision making of all hostile and friendly entities not controlled by humans is directed by agent-based technology. If a human decides to "log in" as a particular entity, he/she may choose to view recommendations generated by the agent for that entity. Even if the human operator chooses not to view recommendations, the agent recommendations are still logged by the computer. This enables direct comparison of human to agent decision making. We expect these capabilities will facilitate skill acquisition, decision making, skills assessment, and human/team performance modeling.

AEDGE agent capabilities enable more detailed and innovative approaches to measurement and modeling of individual and team workload, communication and decision making. Tracking the number and type of recommendations generated by the agent at any given time contributes toward new ways of conceptualizing and representing cognitive workload of individuals and teams. Agent-based recommendations may also serve as a standardized benchmark by which human tactics and decisions can be compared. In addition, the AEDGE platform can operate through speech – operators can speak to the system using predefined jargon, request tasks be performed or information

provided/transferred, and the agents will respond verbally to the speech-driven requests, using voice generation technology. All agent communications with each other, as well as to humans, are transcribed, logged to data output files, and are available online.

The AWACS-AEDGE was conceived through cognitive and functional analysis of team member roles, responsibilities, and decision making (Dalrymple, 1991), to optimize generalizability of results to operational settings. Systematic descriptions of

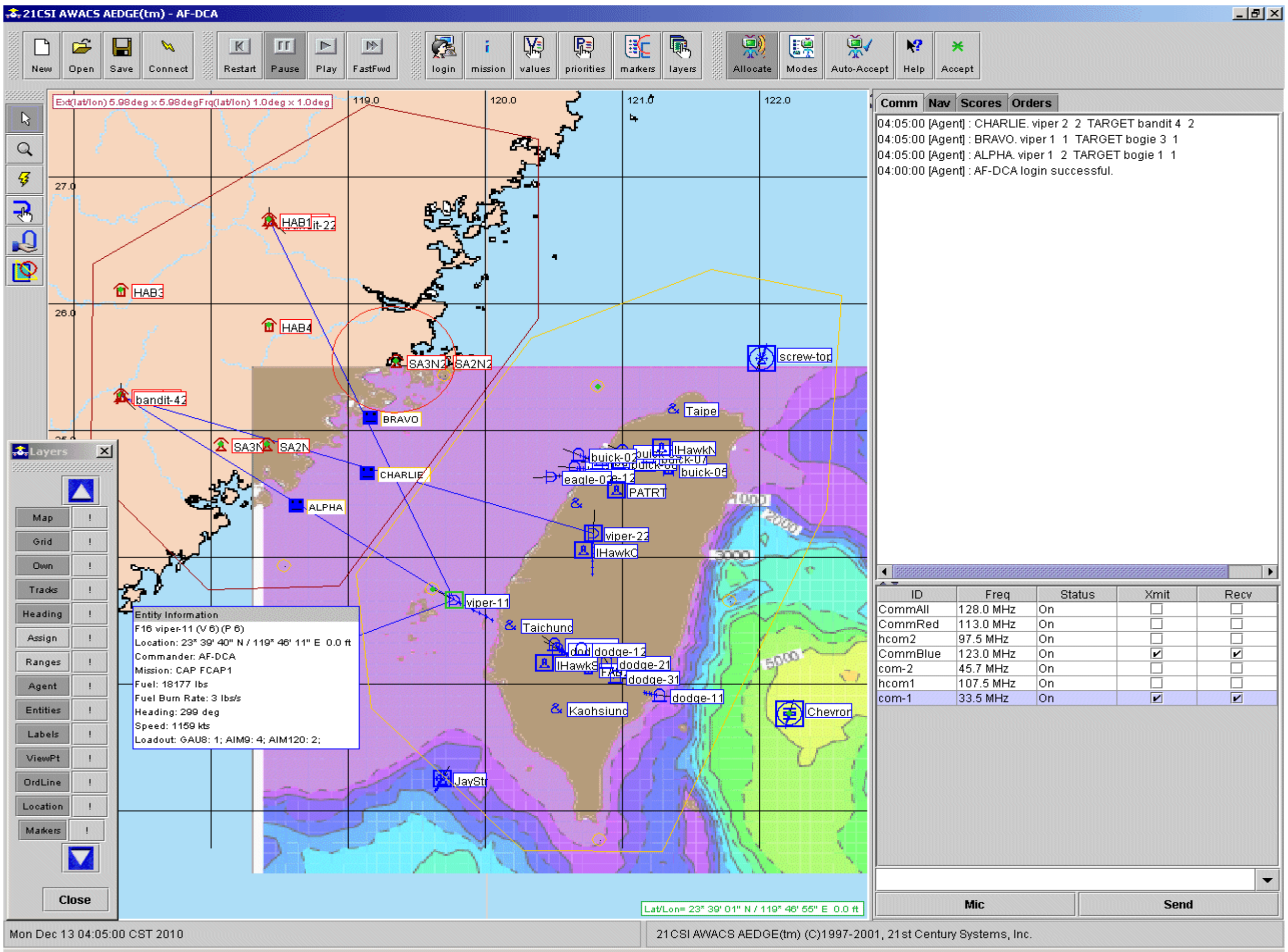


Figure 1: AEDGE Screenshot

AWACS roles, responsibilities, requirements, interdependencies, tactics, strategies, and task demands were collected from subject-matter experts, cognitive task analyses (Fahey, Rowe, Dunlap, & DeBoom, 1997; MacMillan et al., 1998) and focal-group interviews (Elliott et al., 1999; Elliott et al., 2001). These data were examined to identify decision events, which were generic to performance, regardless of mission scenario, and likely to

bottleneck under high tempo situations and sustained operations (see Elliott, et al. this volume).

AEDGE Architecture

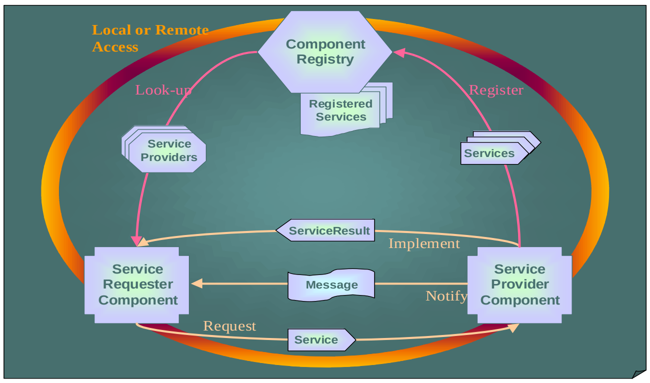


Figure 2: SRSP Protocol Interactions

The AEDGE product is based on an extensible distributed component-based architecture, which defines entities, agents, roles, and their interactions. The interaction and communications among AEDGE elements are based on the Service Provider/Service Requester Protocol (SPSRP), using flexible services and messages to exchange information between any two components (Barnes, Petrov, Elliott, & Stoyen, 2002).

In SPSRP, Service Providers implement a number of services and register service-templates with a Component Registry, which maintains the location of all components and the services provided or required by each. The registry is used by Service Requesters to locate components that provide the services required by the requester. After the requester is matched with one or more Service Providers, a direct connection is established between Service Providers and Service Requesters. This prevents the Registry from being a service dispatcher and a potential bottleneck.

Let us consider the interaction between users (via user interface components) and agent components. In most cases users will interface with specialized Agents, called Agent Managers. The managers are designed to coordinate, synchronize and manage the work of multiple "worker" agents. Without an Agent Manager, the user will need to interface with each "worker" agent individually. Using the Manager, an individual is able to issue higher level requests (e.g., "Send me your current recommendations") by letting the Agent Manager (who knows the capabilities of its workers) to distribute and correlate individual agent tasks. The Service Requester then sends Service objects

directly to one or more Service Providers, who respond with Service Result objects. A Requester may wish to subscribe for service updates, in which case the Service Provider will send a Message object to the requester every time it needs to advertise an update; it is up to the Requester to respond to that message by requesting the actual update (i.e., data is advertised, not pushed, to avoid client-side congestion).

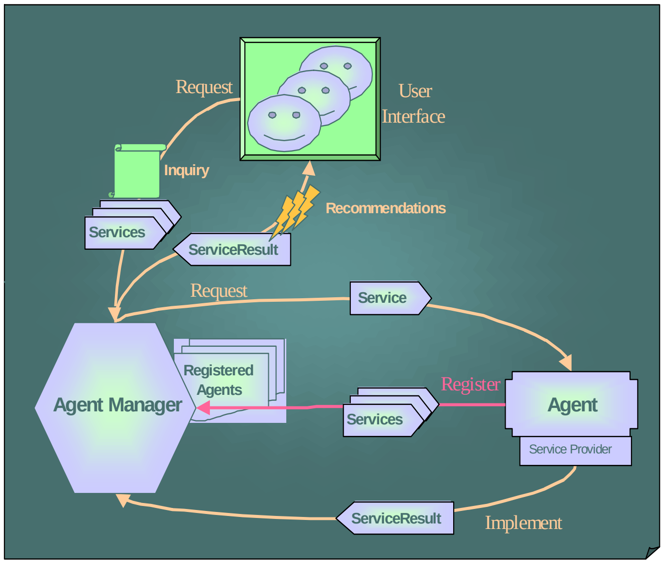


Figure 3: User Request

In Figure 3, we see the user may trigger a request for recommendations, which is sent to the Agent Manager via a Service Request object. After receiving the request, the Agent Manager finds the best-suited collection of agents to perform the job (it may take one or more worker agents) and forwards specialized Service Requests to each of them. The worker agents formulate their responses (usually, sets of recommendations and rationale) and send them back to the Agent Manager via Service Result objects. The Agent Manager may correlate (and even remove redundant or inconsistent recommendations) all service results and then sends the combined set of recommendations to the user, again via a Service Result object. The user interface component then knows how to extract the recommendations and present them to the human user for evaluation.

AEDGE Decision Algorithms

The AEDGE architecture provides multiple levels of agent-based algorithms. Generic resource allocation, search, and optimization algorithms are a core part of the AEDGE product. Each AEDGE application can use and further extend these fundamental agent algorithms by either providing parameters and applications-specific values, functions and rules, or by combining, modifying or supplying new algorithms. All new and modified algorithms must comply with a well-defined agent interaction interfaces, similarly to the generic algorithms.

Table 1: Sample Decision Making Algorithms
IN_RANGE (TargetCandidate, WeaponCandidate) OR **INTERCEPT_TIME (WeaponPlatform, TargetCandidate) < MAX_TIME** **AND** **Pk (TargetCandidate, WeaponCandidate) > DesiredPk (TargetCandidate)** **AND** **FUEL_TO_INTERCEPT (WeaponPlatform, TargetCandidate) +** **FUEL_TO_BASE (InterceptPoint, WeaponPlatform) < WeaponPlatform.currentFuel**

The AWACS-AEDGE extends resource allocation, optimization, and other algorithms with AWACS WD-specific objective functions and constraints. For example, the AWACS weapon-target allocation algorithm, based on a generic resource-allocation with heuristic function evaluation, defines extended constraints such as Table 1.

Similarly, the AWACS weapon-target allocation algorithms define objective and cost functions for any potential allocation and let the generic allocator agent arrive at a near-optimal set of weapon-target pairings. The objective functions are based on the individual target values (as well as other factors, such as target priorities, probabilities for success and so forth). Cost functions are based on the risk for the team if the allocation is to be committed.

Further, the AWACS-AEDGE agents use the extended algorithms as a model of the desired WD performance. Thus, the agents are able to generate a set of recommendations pertinent to a particular tactical position and the events that lead to it. Such recommendations can either be presented to the user (who may choose to accept or ignore them) or be used for internal evaluation of the user's performance as a function of the similarity of recommended-action versus actually-executed-action. A new application

of the agent recommendation analysis involves the measurement of AWACS WD cognitive workload based on the volume and complexity of agent recommendations at any given time (Chaiken et al., 2001).

To enhance the utility of AWACS-AEDGE as a decision support tool, recommendations must not only be presented to the user in a unambiguous and intuitive manner, but in some cases they may need to be pre-processed to ensure that the human user can maintain strong situational awareness and be alert. For example, in periods of exceptionally high-activity, unsupervised agents may tend to generate large number of recommendations that will be confusing and even detrimental to the human performance. The Agent Manager must thus not only coordinate and synchronize recommendations, but also prioritize and reduce the number of presented recommendations to only the top-most critical ones (Chaiken et al., 2001). Conversely, in periods of a lull, artificially increasing the number of recommendations may help keep the human alert and situationally aware.

AGENT TECHNOLOGY

Intelligent agent technology is rapidly demonstrating its value to operational simulation and training. Within the AEDGE, "agent" is a broadly defined term with three dominant functions. The first involves the simulation of scenario entities, referred to as constructed forces. Related to that is the use of agents to substitute for other human roles, to create “synthetic” team members. The third function is that of decision support.

Constructive forces. Agent technology defines the operating characteristics and behavior of hostile and friendly entities (e.g. speed, radar range, and weapons range of aircraft). Agent specification is complete and detailed to the point where the entire scenario can be played out through a federation of numerous "agents" (i.e., a simulation with no live players).

Synthetic team members. Agent technology was also applied to simulate other WD team members within the AEDGE. The distinction between "agent as constructive forces" and "agent as player" is largely one of degree. However, the latter sort of agent is typically far more complex, as these agents are designed to simulate another simulation

player, not just a battle entity. Such agents give users the option to play with other “live” participants or participate alone, with the simulation acting out other roles in a realistic fashion. This sort of agent also defines the pedagogical goal of the simulation, in the sense that these agents can be used to implement (e.g., set policy for) optimal performance. They can also be used to demonstrate the results of flawed performance. "Player" agents are an extremely useful and yet rare capability for team task simulations. However, their development is expected to increase given the great utility of allowing individual training within a team-like context. Both entity and player agent technology are equally important to our effort. The former sense is what gives the AWACS-AEDGE its fidelity to the real task; the latter sense provides both the model of normative behavior the user should strive for and the means (algorithms/knowledge) to effectively accomplish that behavior.

Decision Support. The third manner in which agent technology was utilized is to provide decision support. This type of agent is not so much a simulation of a player (or simulation of an entity) but a simulation of a "coach" or "adviser." This variant of agent can be very broad, and the distinction between such agents and operational interfaces can be blurry because such agents manifest themselves through the interface. For instance, such agents can be imbued with the capability to: (a) seek out information over distributed networks, (b) search through information databases, (c) manipulate information through filtering, transforming, aggregation, and fusing of multiple, independent information steams; and (d) report information to the human requester. There may also be multiple agents working on several tasks at any point of time, e.g., several agents monitoring and filtering information from disparate channels, agents to aggregate and fuse relevant information, agents to select an appropriate visualization of the data to report, and so on. Some agents may be imbued with a high level of autonomy, allowing them to make critical recommendations based on information found without human solicitation or guidance.

In the AEDGE, the experimenter can control the autonomy and configuration of the decision aide agent. If the agent is allowed to make all decisions, the scenario is effectively being run independently of any human intervention. This allows (a) assessment of reliability of recommendations, (b) assessment of effects of uncertainty in

a dynamic environment, and (c) investigation of "what-if" scenarios, where algorithms underlying recommendations are manipulated.

DMT-RNet: CONNECTIVITY

The AWACS DDD-Net was the first step of implementing and demonstrating the feasibility of the DMT-RNet that allowed distributed simulations over the Internet in real-time (Barnes, et al., 2001). Aptima, Inc. worked with faculty and staff at the University of Central Florida (and associated Institute for Simulation Technologies [UCF/IST]), the University of South Florida, and researchers located at Brooks Air Force Base (Brooks City Base) to test the feasibility of the project (Entin, Serfaty, Elliott, & Schiflett, 2001). The DDD-Net linked the different locations (as shown in Figure 4 labeled DDD) to form a simulated C2 infrastructure that allowed multi-role missions, data collection, and web-based feedback while running a complex C2 scenario.

Different parts of the network included Internet-2 (I-2) connections for improved speed, performance, and reliability. The DDD-Net achieved and maintained a synchronized connection for an AWACS simulation involving 16 participants. Simultaneously, observers at each location rated performance using web-based tools that allowed immediate data pooling, analysis, and feedback, within 10 minutes after data input was complete.

While the previous effort connected several nodes located at various sites, the nodes were only extensions of the same (DDD) platform. The next effort of this project extended the interoperability capabilities, as well as developed additional platforms (Barnes, Petrov, et al., 2002). The AWACS AEDGE™ (as discussed above) was successfully connected to the Command, Control, and Communications Simulation Training and Research System (C3STARS) at Brooks AFB, TX to simulate the weapons director roles within the AWACS (see Figure 4, labeled AEDGE). This entailed one-way communication from the C3STARS to the AEDGE. Position, heading, altitude, and identification data were all communicated, and all information was accurate with the exception of some problems with the heading information. However, this test was not run in the reverse direction, with information going from the AEDGE to the C3STARS,

although it is believed that it would likely work. Another potential advance would involve utilizing the AEDGE agent recommendation information and sending it to the C3STARS operator.

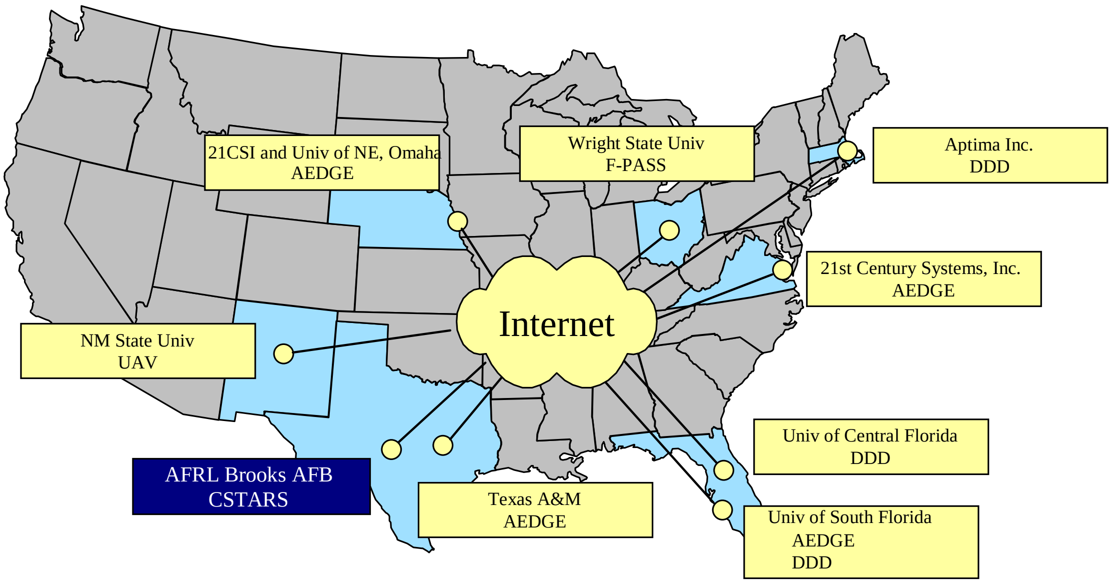


Figure 4: DMT-RNet Locations

An UAV platform developed by Cooke and Shope (see this volume for a detailed description) was connected at New Mexico State University to a cadre of fighter-pilot simulators using the F-16 4-ship Flight Performance Assessment Simulation System (F-PASS) developed by NOVA Technologies, Inc. As shown in Figure 4, a successful test was run linking the C3STARS, the UAV, and the FPASS simulators (Barnes, Petrov, et al., 2002). The C3STARS and UAV simulators utilized T1 lines, while the FPASS used a 56K baud line. While connected, all three of the systems participated in a "test exercise." The FPASS accurately displayed both the UAV and the C3STARS-generated entities. The C3STARS displayed and tracked all entities involved.

As an example of how these varied simulators were integrated, the UAV found ground threats and this data was sent to the C3STARS. The C3STARS then used these data to direct friendly forces, including both FPASS and C3STARS-generated entities.

However, one limitation this test faced was the UAV was set to transmit data only. It did receive data from the C3STARS, but there was no way for it to utilize the data. Also,

voice communications were sent over phone lines. In the future, voice communication will be integrated in the network.

TECHNICAL ISSUES

There were many technical issues that came up while the DMT-RNet was being set up (Barnes, et al.,, 2001). Different parts of the network were connected at different speeds. Brooks Air Force Base used a T3 connection, while other sites had only T1 connections. Some of the network used part of the backbone of Abilene, one of the main I-2 branches. Even with the lowest speed being a T1 connection, bandwidth was an issue, mainly because of the mismatched speeds. To make things more complicated, not only was I-2 employed, but the secure Defense Research and Education Network (DREN) was utilized for part of the network.

Getting all of these different nodes, firewalls, and networks to link together was at times a complex undertaking. Incoming and outgoing security was an issue; especially considering the fact that one of the nodes was at Brooks Air Force Base. There were firewalls to be dealt with that were necessary for security, but they hindered the speed of the network and made the operation more complex. Brooks in particular had not only firewalls, but also internal and external routers and a proxy server to be dealt with as well.

Technical issues became more complex as the multiple simulators were being integrated. Developed individually, these simulators were not originally intended to be linked with other types of simulators in a DMT-RNet type of environment. Solving these interoperability issues during the development of the platforms, and having them work together in a way that enables this type of research was one of the major accomplishments of the DMT-RNet.

Currently, the DMT-RNet uses unclassified information. However, being connected on a military base raises network security issues that are important. Base networks are under constant attacks from people trying to hack in, consequently there are stringent firewalls that the DMT-RNet has to navigate. In the future, security issues will be at least as complex as they currently are. Different research networks will be formed and

communication between them may be an issue, but I-2 technology will form a stable base that will make that a more possible venture.

DISCUSSION

We expect the platforms within DMT-RNet to enhance research, training, and performance in complex high-tempo scenarios. The benefits of this general approach to STE-based research is detailed elsewhere (Schiflett & Elliott, 2000). To summarize briefly, the AWACS AEDGE™ was developed to primarily to support trainers and researchers. In fact, every characteristic and feature within this platform was developed to empower trainers and researchers with regard to methods, measures, manipulations, and transfer of training. First, internal validity is enhanced by providing researchers with more detailed performance measures, increased scenario realism, ease in generating scenario events, agent-based performance models, and comprehensive data output files. In addition, further control is provided to team performance researchers through the provision of synthetic team members—thus allowing investigations of performance within more highly controlled team contexts. It provides trainers with online scenario revision capabilities and visual online performance feedback for operators. Finally, this system was developed to enhance external validity—the degree to which research transitions to the operational performance environment. This was accomplished through comprehensive cognitive task analyses of the operational performance domain. While use of this system is no guarantee of good training or research per se, we hope it will accomplish its purpose—to provide tools that empower experts to more easily accomplish research and/or training goals.

These efforts toward the DMT-RNet have shown the great potential that exists for the integration of simulators into a common network, one that can be utilized not only for training purposes but also for training research. Each of the DDD, AEDGE, UAV, FPASS, and C3STARS platforms were developed independently, without plans for integration. However, tests have been successfully run showing them working together, generating and displaying entities from each of the various systems in a common battlespace. Integration barriers are being taken down, allowing for interoperability

capabilities previously undreamed of. This will allow for high-quality collaborative research, where the strengths of each simulator and platform are put to use in a complementary way. The creation of this infrastructure is more than a demonstration of technology. First, the platforms themselves offer unique capabilities, regarding scenario realism, experimental control, and performance measures to experimenters. The use of a common platform allows comparison of diverse programs of research, each focused on a different aspect of performance, albeit training, interface technology, information distribution, or fatigue countermeasures.

Even so, why connect the platforms? Certainly, the distribution and portability of these platforms have self-evident benefits for trainers—training can occur among distributed trainees, deployed in remote sites. But what is the benefit for researchers? First, there is great importance in performing research on multi-team system performance. Operational teams are often assigned ad hoc, with team members and teams having diverse perspectives and little familiarity with each other. Distributed team research can capture these inherent differences faced by DMT teams. Teams in different locations would have diverse individuals, trained in diverse locations, with different curricula, by different trainers—thus capturing relevant and realistic diversity in operations.

In addition, operational DMT generates questions regarding the type and nature of joint mission planning, multi-team coordination, and joint debriefing procedures. DMT teams encompass diverse teams, such as cadres of fighter pilots, cargo and refueling aircrew, and various C2 platforms. DMT itself does not lend itself as well to experimental design. DMT resources are devoted more toward training in itself, subjects / resources are difficult to procure, and experimental manipulation more difficult to achieve in a context rich in confounding variables and low in statistical power. The connection of diverse internet-based platforms allow university-based researchers to investigate questions of skill acquisition in multi-team context, to easily manipulate distribution and display of information and performance feedback, and to study processes of joint mission planning and debriefing. Thus, DMT-RNet will serve as a scientific bridge for the enhancement of operational distributed mission training.

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